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Tube Welding

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Introduction

Tube welding implies many things to many people depending on the industrial market segment or segments on which they focus most of their business activity. Tube welding covers the gamut from autogenous orbital gas tungsten arc welding (GTAW) of process gas tubing for the production of electronic components and computer chips, through welding of tubes in tubeplates for boilers, and a wide variety of other applications. The focus of this article is the welding of longitudinal seams in roll-formed and welded tubing produced from coil stock, and the fabrication of these welded tubes into useful products. This can be by straightforward tube to tube butt joining of tube ends, or more complex geometries, particularly including the very dynamic and growing area of tubular hydroformed products in the automotive industry.

The distinction between tube and pipe, based on wall thickness limit and/or wall to diameter ratio), is a little different from industry to industry. For the purposes of this article tubing is considered as having a wall thickness of up to 1/4-in. or less and a diameter of 6-in or less, while pipe has a wall thickness above 1/4-in. and a diameter greater than 6-in. Having said this, the author has done development work for a stainless steel structural tubing producer at wall thicknesses up to 0.315-in., hence the rather blurred nature of the definition.

As the title suggests, this article concentrates on welded tubing.

Tubing can also be produced in seamless varieties, and involves techniques including piercing and rolling in the case of ferritic steels, or extrusion in the case of aluminum alloys. Seamless production of steel tubing and pipe is typically used on heavier wall tube and pipe intended for highly stressed applications such as drill pipe where the higher cost of seamless versus welded tube or pipe is justified.

The majority of welded tubing is produced from coil stock. To produce tubing, the coil is mechanically slit to width representing the developed circumference of the nominal tube diameter. The slit coil, commonly known as skelp, is typically progressively roll formed in a tube mill, such that the edges are brought together to be welded along the longitudinal seam. Forming is typically done to form round tubing that is mechanically finished to size in round form. However, a substantial quantity of tubing is formed in square or rectangular form, for finished sizes of similar proportions. Other shapes such as D-shaped tubing and more complex geometries are also produced, but represent a smaller proportion of overall production.

Tubing is manufactured in a wide range of alloys, both ferrous and nonferrous, and in a wide variety of wall thicknesses, and diameters. Typical tubing materials range from low carbon through high strength steels, stainless steels (predominantly austenitic, but including ferritic and duplex stainless grades), aluminum alloys, copper alloys, nickel alloys, and even titanium alloys. The majority of tubing is in the wall thickness range of 0.015-in. to 0.250-in although both thinner and thicker wall tubing are produced for specific applications.

Longitudinal Seam Welding of Tubing

The choice of welding process is largely dependent on the material being welded and the end-use application. The processes used most widely are as follows:

- Arc Welding GTAW and PAW - single torch and multiple torches
- Laser Welding - CO2 and Nd:YAG
- High Frequency Induction Welding and other variants of resistance welding

Arc welding is predominantly used for stainless and higher alloy materials to produce the highest quality joints in higher value products.

High frequency (HF) induction welding is the predominant process of choice for welding ferritic steels. HF welding has typical production speeds roughly ten times higher than arc or laser welding for production of steel tube. The tolerance window for HF steel tube welding is relatively large, but is much smaller for stainless steels and non-ferrous materials. Welding speeds for HF welded steel tube can be as high as 300 ft/min, with the speed obviously varying depending on the tube wall thickness and welding power available.

Arc welding, predominantly by single torch GTAW, but also with two, three, or even four GTAW torches in line, is used most widely for austenitic stainless steels such as 304/304L and 316/316L, but is also used widely for non-ferrous tubing in nickel-based alloys, aluminum alloys, and copper alloys. Plasma arc welding (PAW), particularly in the keyhole mode, is also used quite widely on thicker wall tubing because of its ability to penetrate wall thicknesses of up to at least 8 mm in a single pass, closed-butt joint configuration. These wall thickneses can readily be achieved when aided by simultaneous use of one or more GTAW torches for preheating (lead torch) and blending of undercut resulting from keyhole PAW by use of a trail GTAW torch.

Laser welding is a fast emerging process of interest for seam welding of tubing. With the commercial availability today of carbon dioxide lasers up to 12 kW, and Nd:YAG lasers up to 5 kW, stainless steels and other alloys can be welded at high speed, although much tighter control of fit-up is required to achieve consistent weld quality in a high production environment because of the much more highly focused energy source compared to, for example, a GTAW arc. The beam can be partially defocused to provide more tolerance to fit-up variation, but only at the expense of line speed. Laser costs are coming down, but the high development costs mitigate against the price of lasers falling is a way akin to computer prices, much as this would be desirable from an end-user perspective. Laser costs are typically an order of magnitude higher than those of even relatively sophisticated arc welding equipment. For example, a 12 kW CO_2 laser would cost $600K, while a 5 kW Nd:YAG laser costs $350K. Bear in mind that this is the cost of the laser, not the tube mill.

Tube to Tube Welding for Spaceframe Vehicle Structures

There is currently a very strong and growing interest in hydroforming

of tubular products, particularly for the automotive market. Interest is very evident from the steel and aluminum industries as a major market for steel and a major potential market for aluminum alloys, and from the tubing producers, as well as the automotive companies and their major suppliers. Hydroforming is a separate field in it own right, as a sophisticated metal forming technology allied to metal stamping and pressing technology. While of great interest, it is not the intent of this article to focus on the details. The primary driver for use of hydroformed tubular products in an automotive spaceframe vehicle structure is to increase stiffness while further reducing body weight to enhance overall fuel economy and handling performance. This is obviously a major focus of the automobile manufacturers and involves a huge automotive supplier network to varying degrees depending on their product mix. Very large automotive suppliers such as Tower Automotive and Magna are already highly involved with hydroformed tubular products, and have already begun supplying such parts to the car-making industry, albeit in relatively small quantities, and for a limited number of vehicles at this time. The growth potential, however, is huge.

Tube Welding Equipment for Longitudinal Seam Welding

There are naturally a large number of equipment producers and suppliers for tubemaking with arc, resistance and laser welding processes. A listing of some of the major equipment producers for each process is as follows;

- Rafter, T&H Machine, and Addison for tubemaking equipment and tooling for arc welding and laser welding systems
- Liburdi-Pulseweld, Hettinger, and others suppliers such as ESAB/L-Tec for arc welding equipment
- Trumpf, Rofin-Sinar, and Lumonics for laser welding equipment
- Elva, Emmedi, Thermatool, and Yoder, for HF, ERW and resistance welding systems

This list is far from exhaustive, and is only intended to indicate the names of major players in each of the equipment categories. These are companies known to the author, and does not represent an endorsement of one producer over another.

Orbital Welding of Tubing

Orbital welding for tubing refers to circumferential welding of tube-to-tube butt joints, to join lengths of tubing end to end, or tubes to fittings including flanges, elbows , branch connections in tubing systems, etc. While orbital welding can be performed manually, it is usually performed by mechanized equipment. Orbital welding can be preformed with a number of welding processes, but by far the most common for tubular products in all metals and alloys, is GTAW. For tubular products welding is usually carried out autogenously, i.e. without filler wire addition to the weld pool, although filler wire can be added by mechanized cold wire feed systems if required. Equipment for tube welding usually involves a clamp-on system for tube diameters from 0.125-in. through 6 to 8-in., and track mounted systems for larger diameters. Heads can be of an enclosed (for metals such as titanium) or open design as far as gas shielding of the joint area during welding. The head design is either a U-shape or of a split clam-shell design to facilitate clamping to the fit-up tube joint. The head remains stationary while the electrode is rotated within the body of the welding head. Such systems maximize the consistency, quality and productivity of tube-to-tube butt welding operations.

Equipment is available from a large number of producers around the world, many of which are based in California. Equipment producers include Liburdi Pulseweld (including the previous Dimetrics and Hobart equipment ranges), Arc Machines, Polysoude, MK Products, and ST International.

The systems available today range from relatively simple devices through sophisticated computer controlled equipment with multiple segment programming for different welding positions around the fixed axis of the joint.

About Edison Welding Institute

EWI is very actively working in the tubemaking market through our member companies, through our own in-house equipment capabilities in HF, arc and laser welding, and through troubleshooting tube production issues. EWI works with this industry through our Primary Metals Industry Team, whereby we categorize tubing (and pipe) producers with metals producers making sheet, plate, extrusions and

other commodity products. As the market for hydroformed tubular products for automotive and applications gathers momentum, we are experiencing increasing synergy between the Primary Metals Industry and the Automotive Industry. To this end, EWI has teamed with the International Tube Association (ITA), through their North American Board members to present four seminars on seam welding of tubing in the last two years. Average attendance at each of these events has been 55. A conference on tube welding for hydroforming applications has also been held:

EWI/OSU/ITA Conference 'International Conference on Tube Welding for Hydroforming Applications' - Sept. 21-22, 1999, Holiday Inn (I-270 at Rt23), Columbus, Ohio.

The two day conference is also jointly sponsored by the Ohio State University (OSU) Net Manufacturing Center (NMC) which has a 25 member consortium on tubular hydroforming, many members of which are also among the 400 industrial members of EWI. OSU's NMC is the only U.S. university with a laboratory-based hydroforming research capability, and the university campus is only 5 minutes from EWI in Columbus, Ohio. Anyone whom is interested in more information about the seminar series and the conference in tube welding and hydroforming should contact the author at the address shown at the end of this article.

EWI, in association with OSU, is also launching a major initiative on tube welding, hydroforming, engineering performance and simulation, and prototyping for automotive applications. This is a multimillion dollar suite of projects for which industrial sponsorship will soon be sought. A recent technology briefing in Detroit attracted over 150 attendees. More information can be gained by contacting the author.

EWI has a comprehensive range of projects within our Cooperative Research Program (CRP), the results of which are available exclusively to industrial member companies, on welding of both steel and aluminum alloys for tubular spaceframe vehicles applications, using arc, resistance, and laser welding processes.

For more information on all aspects of tube welding, tube welding seminars, and the conference on tube welding for hydroforming

applications, please contact the author as follows:

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